Proceedings of EuroHaptics 2004, Munich Germany, June 5-7, 2004.

A Haptic Training Simulation for Paper Conservation: Preliminary Results

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Abstract. This paper presents the preliminary development and testing of a prototype haptic simulation environment for skilled manual tasks applied in the field of paper conservation. The procedure of backing removal involves the gradual removal by scalpel of aged and degraded card backing materials, adhered to fragile works of art on paper. A backing removal simulation was developed for the Reachin® display system by extending the existing API class library in C++. The simulation environment and interface was created using VRML and Python. It is intended that the prototype be developed as a training tool for conservation education, allowing students to develop manual skills in the virtual environment prior to treating valuable works of art. Initial tests were conducted with a group of randomly selected, novice conservation students to establish if learning and skill development takes place in the context of repeated simulation training sessions.

1 Introduction

In paper conservation training, students are required to gain many hours of experience in specific manual tasks. These skills must be acquired for the successful and safe treatment of delicate and fragile works of art. Haptic virtual environments offer a means of creating an enhanced training tool for conservators. Simulated conservation operations, such as backing removal, can be performed without risk to the objects, while students are at an early stage of training. Also being explored is the potential of simulation to accelerate training through enhanced feedback such as visual, aural and touch stimuli. It is intended that the simulation environment will track student progress by compiling statistical data on their performance that can be reviewed by the tutor.

A significant problem for the preservation of works of art on paper is the presence of aged and degraded backing materials adhered to the reverse of original artifacts [1]. The conservation task of removing such backings is the focus for the simulation training tool prototype. Fragile and delicate watercolours or prints can be damaged by the presence of these, usually poor quality, acidic paper or board backings. Mechanical removal using hand tools such as scalpels and spatulas is often the only viable means of detaching the backing. Moisture or solvent based treatments such as soaking or steam humidification can be effective for backing reversal, but are often not appropriate due to the sensitivity of the original object. Mechanical removal, although slow and exacting, allows a greater degree of control and precision.

Fig. 1. A scalpel backing removal of hardboard from paper in progress

The time available in a typical conservation degree course is limited. This often means that students begin by training on genuine works of art. The extended period usually needed for students to master backing removal treatments may be shortened by the use of the simulation based training. It will also allow manual skills to be developed prior to commencing work on valuable artifacts.

Fig. 2. The simulation prototype: a central square, deformable backing area (yellow) is positioned over a non-deformable paper layer (white). The layers share frictional characteristics. A smaller, but otherwise identical square, is provided on the left for the user to explore the simulation prior to commencing the main test area task.

2 The Simulation

In the prototype version, the physical characteristics and dynamic properties of the paper objects and their backings are modelled according to values from existing conservation research and paper industry standards [2], in conjunction with empirical testing by experienced conservation professionals. In the prototype, it is possible to adjust parameters within the simulation for properties such as stiffness, friction, texture relief, and local deformation characteristics. However, this will be extended in future work to include variables that can accommodate a greater range of physical factors such as depth, material type and environmental relative humidity.

The project uses the Reachin® co-located, stereoscopic display system with a PHANTOM® Premium 1.5 3DOF haptic stylus and Reachin® application programming interface (API) version 3.2. In the development of the simulation prototype, two additional classes were created in C++, extending the standard API libraries. The simulation environment scene, including geometry and interface components, was created with Virtual Reality Modelling Language (VRML) and Python.

2.2 Development Approach

The haptic simulation of the selective removal of discrete pieces of cardboard, a fibrous material, by scalpel presents many challenges. Initially a constructive solid geometry (CSG) approach [3], using a Boolean method for the cardboard removal, was considered. This would have the advantage of a "waste" object being created in conjunction with the cardboard deformation. In addition, such a method could have been adapted to create a particle based solid, whereby the fibrous nature of the material could be modelled. The principal drawback of CSG used in this context was the high computational overheads of haptically rendering such an object. The development task would also have been a considerable undertaking in the context of the API being employed. Such methods may be approached in future work, however for the prototype it was decided to proceed with more approachable plastic coordinate deformation method, based on existing elastic deformation classes already supported in the API. This did not provide a complete solution to the simulation requirements, but facilitated the creation of a meaningful prototype, which could then be tested in order to explore the fundamental efficacy of haptic simulation training in conservation.

3 Preliminary Testing: Objectives and Methodology

The objective of the preliminary test programme was to establish if psychomotor learning is taking place in the test subjects as they repeatedly perform a set task in the simulation. Additionally, the tests were used to establish a baseline skill level and evidence of a skill plateau in the simulation context.

Ten randomly selected, novice conservation students were subjected to a series of five, ten-minute tests, over a four-week period, using the simulation prototype. Interaction data including force, orientation and contact values, was collected via the simulation software during each test. The objective measurement of manual and dextrous skills is problematic in the absence of any established standards [4]. In this case a set of key skill factors were identified in consultation with conservation practitioners as assessment criteria for the tests. These corresponded to the essential skill elements of real-world backing removal: applied force and angle of incidence. The level of force applied to the backing is a significant factor. Too low a force will have too little an effect and too great a force may result in fabric damage. The angle of incidence of the scalpel to the object plane must be kept low, in order to gradually remove shallow amounts of backing material. A high angle of incidence increases the risk of penetrating the original paper reverse with the blade. Any contact of the scalpel with original paper when the backing material is removed can result in damage. Each contact incident with the virtual backing and paper was recorded together with the associated force values and angle of incidence.

The data extracted from the first simulation test for each subject was processed and score values were calculated for the three skill elements. A baseline skill level score for the test subjects was established from the initial test data. The data from the subsequent tests was interpreted comparatively to evaluate if skill improvement was taking place.

4 Initial Results

Initial evaluation of performance was judged on two key objective scores: maximum deformation value of the virtual cardboard and the frequency of contact with the virtual artifact reverse. Two novice student skill development types seem to be emerging: the “tentative” and the “over-confident”. Typically, the tentative type maximum deformation score increases by significant increments for the first three sessions, then levels off. (e.g. 6.55, 7.95 8.35, 8.15, 8.2). The over-confident subject scores start at a higher value and decrease. The touch frequency, a count value, is the second indicator of performance. The over-confident types have significantly higher touch counts than their tentative colleagues, but the counts decrease for most cases during the trial. The best performers have high maximum deformation values and low touch counts. Further analysis of additional test data, such as deformation force and angle of incidence, is needed to get a clearer picture of performance development for the prescribed task in the simulation. However, these initial results suggest skill improvement is taking place in the majority of both subject types, in the course of the test sessions.

Reference

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